ОЦЕНКА НА УСЛОВИЯТА ЗА ТОПЛИНЕН КОМФОРТ В ОДЕСКА ОБЛАСТ
ОЦЕНКА УСЛОВИЙ ТЕПЛОВОГО КОМФОРТА В ОДЕССКОЙ ОБЛАСТИ
EVALUATION OF THERMAL COMFORT CONDITIONS IN THE ODESSA REGION

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Резюме

Оценка на условията за топлинен комфорт в Одеска област. Биоклиматическите ресурси характеризират връзката между климата и топлинното и здравословното състояние на човека, особеностите на рекреацията и санитарно-хигиенните оценки на околната среда. Затова за характеризиране на климата се използват различни метеорологични показатели, които отразяват състоянието на човека и зоната на топлинния комфорт. В настоящата разработка ние оценихме влиянието на някои комплексни метеорологични показатели (температура на въздуха, относителна влажност на въздуха и скорост на вятъра) върху топлинното усещане на човека в определен момент от времето през различните сезони за територията на Одеска област с помощта на биоклиматични индекси.

Резюме

Оценка условий теплового комфорта в Одесской области. Биоклиматические ресурсы характеризуют связь климата с тепловым состоянием и здоровьем человека, особенностями рекреации и санитарно-гигиенической оценкой окружающей среды. Поэтому для характеристики климата используются различные комплексные метеорологические параметры, которые отражают состояние человека и зону теплового комфорта. В этой работе мы оценили влияние некоторых комплексных метеорологических факторов (температура воздуха, относительная влажность воздуха и скорость ветра) на теплоощущение человека в определенный момент времени в разные сезоны в Одесской области с помощью биоклиматических индексов.

Abstract

Evaluation of thermal comfort conditions in Odessa region. The bioclimatic resources characterize the connection of climate with the thermal state and health of a human, the peculiarities of recreation and hygienic-sanitary evaluation of the environment. Therefore, to distinguish the climate, various complex meteorological parameters are used that reflect the human condition and the thermal comfort zone. In the present study we evaluated the impact of some complex meteorological factors (air temperature, relative humidity and wind speed) on the thermal perception of a human at a definite time moment in the different seasons in the Odessa region by using bioclimatic indices.

Ключови думи: метеорологични фактори, биоклиматология, биоклиматични индекси, топлинен комфорт, рекреация.
Ключевые слова: метеорологические факторы, биоклиматология, биоклиматические индексы, тепловой комфорт, рекреация.
Key words: meteorological factors, bioclimatology, bioclimatic indices, thermal comfort, recreation.

INTRODUCTION

Among the natural resources climate plays a special role. A human can not be isolated from the surrounding air. Impact of the climate on a human body is called bioclimate. Accordingly, bioclimatic parameters differ from conventional meteorological characteristics as they represent a complex influence of meteorological characteristics of air masses on a human organism: temperature, wind speed, humidity, etc. (Kolotova, 1999).

Bioclimatic parameters in the physical sense characterize features of thermal structure of the environment. Also they are indirect indicators of the thermal field that surrounds a person. The crucial component of bioclimatic indices is air temperature, so the incorporation of the effects of relative humidity and wind speed is expressed in the form of the temperature correction to the ambient temperature, which allows more objectively determine heat perception of a human body and assess comfort (discomfort) of the environment. The main meteorological factors affecting heat perception of a human are air temperature, relative humidity and wind speed. It is known that the same heat perception can be exposed under various combinations of these factors (Katerusha and Safranov, 2009).

Influence of climate and weather on human well-being and health was noticed long ago. Usually it reflects in the psycho-emotional reactions to the weather, climate change, the abnormal changes of physiological processes in the body that lead to deterioration of health, occurrence of clinical disorders, aggravation of illness and even death. Healthy people, as a rule, do not notice changes in the weather. If adaptive mechanisms in a body are not properly coordinated, even a healthy person can experience meteotropic reactions in the form of a lung ailment and decline of health. Adaptive mechanisms do not compensate physiological disorders to a patient and a weakened human (especially with age) (Katerusha and Safranov, 2010).

Impact of meteorological factors on the human body is multifaceted and it is displayed through the particular weather conditions. For instance, the temperature of the air affects the depth and frequency of breathing, blood circulation speed, character of supply of the oxygen to the cells, peculiarities of carbohydrate, salt, fat and water metabolism and muscle work. The influence of humidity on the human body is associated with the regulation of water metabolism. Wind affects comfortable state of a human in warm and cold periods of the year, because it can significantly change the rate of convective heat transfer of the body.

Indicators of thermal perception enable to assess bioclimatic resources of the particular areas, to determine their recreational potential and to resolve a range of problems associated with optimization of bioclimate (Isaev, 2001).

The aim of this work is estimation of complex impact of some meteorological values on thermal perception of a human at a definite time moment in different seasons on the territory of Odessa region.

DATA AND METHODS OF RESEARCH

In this work we used the results of daily meteorological observations of temperature (*t*), relative humidity (*f*) and wind speed (*v*) at 12.00 o'clock in four central months (January, April, July and October) within five years (2003-2007) at eleven stations located in Odessa region (Lubashivka, Zatyshye, Serbka, Rozdilna, Odessa, Ilichevsk, Belgorod-Dniestrovsky, Sarata, Bolgrad, Vilkovo, Izmail).

Climate and weather primarily affect the thermal regime of the organism and its functional activity largely depends on the conditions of heat exchange with the environment. Therefore complex indicators that reflect thermal condition of a human are used for bioclimatic assessments.

In bioclimatology for evaluation of complex meteorological conditions that determine heat perception of a human primarily system of effective temperatures is used: equivalent-effective (*EET*), radiation-equivalent-effective (*REET*) etc.

EET is a temperature under which in the stationary and saturated with moisture air heat perception of a person is the same as in a given combination of air temperature, relative humidity and wind speed. Heat perception of a dressed and naked person under the same meteorological conditions is different. Therefore there were developed two scales of *EET* - «a major scale» for a nude human (equivalent-effective temperature - *EET*) and «normal scale» for a human dressed in common, standard clothing (normal equivalent-effective temperature - *NEET*).

The same thermal perception can be experienced under different combinations of air temperature, relative humidity and wind speed. In this work we used one of the most popular complex bioclimatic indices - *NEET*. It was found using the following equation (Boksha V.G. and Bohutsky P.V., 1980):

$$NEET = 37 - \frac{37 - t}{0.68 - 0.0014f + \frac{1}{1.76 + 1.4v_2^{0.75}}} - 0.29t\left(1 - \frac{f}{100}\right), \qquad (1)$$

where, *t* is air temperature, °C; *f* is relative air humidity, %; v_2 is wind speed (m/s) at the height of 2 m.

Estimation of heat perception of a human by means of *NEET* is performed as follows: 0,1-6 º C - very cool; 6,1-12 º C - cool; 12,1-18 º C - moderately warm; 18,1-24 º C - warm; 24,1-30 º C - moderate heat load,> 30 º C - strong heat load (Hentschel, 1988).

RESULTS OF THE BIOCLIMATIC ASSESSMENT AND THEIR ANALYSES

Thermal comfort occurs when there are such meteorological conditions under which the thermoregulatory system of the body is exposed to the slightest pressure, i.e. there is a physiological rest. One of the most objective indicators of discomfort is a skin state (tremor, redness, excessive sweating, etc.) (Isaev, 2001).

Significant fluctuations of air temperature *(t)* can cause meteotropic reactions of a human. To determine changes in temperature there is a parameter which is called *interdiurnal temperature variation*. Interdiurnal fluctuations within 0-2°C are neutral or indifferent (i.e. comfortable) for humans. If temperature from day to day varies from 2 to 4°C, the human body adapts to it. Interdiurnal temperature variation within 4-6°C is noticeable and more than 6-8°C - palpable. For a person diurnal amplitude of 8-12°C is sensitive and higher than 12°C - irritating. Thermal conditions have a great influence on the heat exchange of the human body with the environment. The possibility of hypothermia or overheating or thermal comfort depends on the terms of heat transfer. So, interdiurnal temperature variation value is taken as bioclimatic criteria that may be associated with the passage of atmospheric fronts (Isaev A.A., 2001). The results of the calculations are given in Table 1.

Таблица 1. Повторяемость (%) межсуточной изменчивости температуры (t)
Table 1. Frequencies (%) of interdiurnal temperature variation (t)

Station №	January						April					
	Air temperature, ºC						Air temperature, ºC					
	0-2	2-4	4-6	6-8	8-12	>12	0-2	2-4	4-6	6-8	8-12	>12
1	46,7	29,3	16,7	5,3	1,3	0,7	48,3	28,3	11	9	3,4	0
2	50,7	26	13,3	7,3	2	0,7	43,4	28,3	15,2	6,2	6,9	0
3	49,3	24	18	4	4,7	0	47,6	26,9	15,2	6,9	3,4	0
4	48,7	28	13,3	6,7	2,7	0,7	46,9	24,1	15,9	8,3	3,4	1,4
5	46,7	30,7	13,3	5,3	3,3	0,7	51	30,3	13,8	4,1	0,7	0
6	46,7	34	12	4,7	2	0,7	57,2	24,8	12,4	4,8	0,7	0
7	48	30	13,3	5,3	2,7	0,7	52,4	29	9,7	7,6	1,4	0
8	42,7	29,3	17,3	9,3	1,3	0	40,7	31,7	13,8	6,9	4,8	2,1
9	44,7	32	12	9,3	2	0	44,1	30,4	13,1	6,9	4,1	1,4
10	45,3	27,3	17,3	6,7	2,7	0,7	51,7	25,5	12,4	5,5	4,1	0,7
11	36	37,3	16	9,3	0,7	0,7	47,6	26,2	15,9	6,9	3,4	0
Station №	July						October					
	Air temperature, ºC						Air temperature, ºC					
	0-2	2-4	4-6	6-8	8-12	>12	0-2	2-4	4-6	6-8	8-12	>12
1	46	32	12,7	5,3	3,3	0	43,3	32	14,7	6	3,3	0,7
2	47,3	30,7	12,7	6,7	2	0,6	40,5	33,1	13,2	9,1	2,5	1,6
3	50	26	14	8	2	0	43,3	31,3	14	8,7	1,3	1,3
4	50,7	29,3	10,7	6	3,3	0	42,7	32	12	8,7	3,3	1,3
5	63,3	22	10	4,7	0	0	53,3	30	10,7	3,3	2	0,7
6	62,8	26,4	8,1	1,4	1,3	0	57,3	28,7	9,3	2,7	2	0
7	57,3	29,3	10,7	2,7	0	0	49,3	30,7	10,7	6	3,3	0
8	52	31,3	10,7	4,7	1,3	0	42	29,3	14,7	6,7	6	1,3
9	48,7	32	10,7	4,6	4	0	48,7	28	9,3	6,7	6	1,3
10	53,7	27,3	15,3	2,7	2	0,7	46	26,7	14	8,7	4	0,7
11	52	31,3	10,7	4,7	1,3	0	50,7	23,3	14,7	6,7	4	0,7

Станции: *1 - Любашёвка; 2 - Затишье; 3 - Сербка; 4 - Раздельная, 5 - Одесса; 6 - Ильичёвск; 7 - Белгород-Днестровский; 8 - Сарата, 9 - Болград, 10 - Измаил; 11 - Вилково*
Stations: *1 – Lubashivka; 2 – Zatyshye; 3 – Serbka; 4 – Rozdilna; 5 – Odessa; 6 – Ilichevsk; 7 – Belgorod-Dniestrovsky; 8 – Sarata; 9 – Bolgrad; 10 – Izmail; 11 – Vilkovo*

The table shows that interdiurnal temperature variation in Odessa region often is not felt by the human body (0-2°C). Maximum repeatability of these values is observed usually in coastal areas. In January and October at 64% and 73% of the stations respectively, interdiurnal temperature variation exceeds 12˚C which is irritable to humans. In April repeatability of such values is much lower (only 36% of stations), and in July it is generally minimal (18%). Relative humidity comfort zone for healthy people ranges from 45 to 80%. During drought, when humidity does not exceed 30%, water yielding capacity of the body increases dramatically. At *f* > 80% evaporation is difficult, heat perception is more uncomfortable. Patients with hypertension and coronary atherosclerosis are very sensitive to fluctuations in relative humidity. These patients have the majority of attacks at a relative humidity of 80-95% (Vrublevska, Katerusha, 2005).

In Table 2 the repeatability of gradations of relative humidity is given. The table shows that in January comfortable humid conditions prevail throughout the region. Their repeatability is 49-61%. But often (with repeatability 28-48%) relative humidity exceeds 80%. In April comfortable humid conditions preponderate with recurrence of 55-67% in the coastal districts of Odessa region (Odessa, Ilichevsk Belgorod-Dniestrovsky, Vilkovo). However, in these areas there is the most frequent repeatability (9-24%)

Таблица 2. Повторяемость (%) относительной влажности (f)
Table 2. Frequencies (%) of relative humidity (f)

Station №	January			April		
	Dry air < 45%	Comfortable 45 - 80%	Very wet > 80%	Dry air < 45%	Comfortable 45 - 80%	Very wet > 80%
1	2,6	51	46,4	70	24	6
2	2,6	56,8	40,6	66,7	28	5,3
3	3,2	54,8	42	56	41,3	2,7
4	3,9	51	45,1	50,7	42,7	6,7
5	3,2	49,7	47,1	19,3	56,7	24
6	3,2	49	47,8	13,3	66,7	20
7	1,3	53,5	45,2	22,7	61,3	16
8	2,6	55,5	41,9	59,3	35,3	5,3
9	5,2	58,7	36,1	64,7	29,3	6
10	11,6	60,7	27,7	64,7	30	5,3
11	1,3	53,5	45,2	35,3	55,3	9,3
Station №	July			October		
	Dry air < 45%	Comfortable 45 - 80%	Very wet > 80%	Dry air < 45%	Comfortable 45 - 80%	Very wet > 80%
1	62,6	32,2	5,2	19,3	63,9	16,8
2	52,3	40,6	7,1	22,2	62,7	15,1
3	52,2	42,6	5,2	13,6	71,6	14,8
4	49,7	43,9	6,4	15,5	68,4	16,1
5	20,6	71,6	7,8	7,7	63,9	28,4
6	16,2	66,2	17,6	4,5	69	26,5
7	16,8	76,8	6,4	5,2	73,5	21,3
8	56,8	36,1	7,1	22,6	63,2	14,2
9	60,7	34,8	4,5	23,9	63,9	12,2
10	67,1	30,3	2,6	31	60,6	8,4
11	32,2	63,9	3,9	8,4	72,9	18,7

Станции: *1 - Любашёвка; 2 - Затишье; 3 - Сербка; 4 - Раздельная, 5 - Одесса; 6 - Ильичёвск; 7 - Белгород-Днестровский; 8 - Сарата, 9 - Болград, 10 - Измаил; 11 - Вилково*
Stations: *1 – Lubashivka; 2 – Zatyshye; 3 – Serbka; 4 – Rozdilna; 5 – Odessa; 6 – Ilichevsk; 7 – Belgorod-Dniestrovsky; 8 – Sarata; 9 – Bolgrad; 10 – Izmail; 11 – Vilkovo*

of very humid conditions (> 80%). In the rest of the region area dry conditions prevail. In July favorable characteristics most often are observed in Belgorod-Dniestrovsky, Odessa, Ilichevsk and Vilkovo with repeatability 64-77%. At the same time, exactly in Ilichevsk the most often (18% of cases) the air is very humid. In other stations dominates dry air (f <45%). In October comfortable humid mode dominates in entire Odessa region (repeatability 61-74%).

The next stage of the work is calculating of *NEET*. The results are presented in Table 3. From this table we can see that in January throughout Odessa region dominated (with repeatability 84-97%) very cold conditions. And even in this time of year almost at 50% of stations comfortable conditions are possible. The most frequently (repeatability 3-4%) they are observed in Sarata and Vilkovo respectively. In April heat perception «very cool» prevails in Odessa, Ilichevsk, Belgorod-Dniestrovsky with recurrence approximately 55%. In other areas «cool» thermal perception is more common. The most comfortable situation is in the southern territories and Serbka. In July

Таблица 3. Повторяемость (%) НЭЭТ (°C)
Table 3. Frequencies (%) of NEET (°C)

Station №	January						April					
	NEET, °C						*NEET*, °C					
	0,1-6*	6,1-12	12,1-18	18,1-24	24,1-30	> 30	0,1-6	6,1-12	12,1-18	18,1-24	24,1-30	> 30
1	97,4	2,6	0	0	0	0	34,7	53,3	12	0	0	0
2	97,4	2,6	0	0	0	0	28,7	58	13,3	0	0	0
3	92,9	6,5	0,6	0	0	0	26	47,3	25,3	1,3	0	0
4	95,5	3,9	0,6	0	0	0	26	52	22	0	0	0
5	93,5	6,5	0	0	0	0	54,7	41,3	4	0	0	0
6	94,8	5,2	0,0	0	0	0	54,7	42,7	2,7	0	0	0
7	96,1	3,2	0,7	0	0	0	55,3	40	4,7	0	0	0
8	87,1	10,3	2,6	0	0	0	21,3	49,3	27,3	2	0	0
9	90,3	9,7	0	0	0	0	22	58,7	19,3	0	0	0
10	89	11	0,0	0	0	0	35,3	45,3	19,3	0	0	0
11	84,5	11,6	3,9	0	0	0	27,3	47,3	24,7	0,7	0	0
Station №	July						October					
	NEET, °C						*NEET*, °C					
	0,1-6	6,1-12	12,1-18	18,1-24	24,1-30	> 30	0,1-6	6,1-12	12,1-18	18,1-24	24,1-30	> 30
1	0,7	3,2	21,9	61,3	12,9	0	39,4	39,4	20,6	0,6	0	0
2	0,6	3,9	20,7	60,6	14,2	0	31	42	21,4	4,8	0,8	0
3	0	1,3	14,8	52,9	28,4	2,6	27,1	27,1	33,5	12,3	0	0
4	0	3,9	12,9	64,5	16,8	1,9	31	31	30,3	7,7	0	0
5	0	0,6	16,8	73,6	9	0	27,7	44,5	25,2	2,6	0	0
6	0	3,3	18,2	66,2	12,3	0	26,5	38,7	31,6	3,2	0	0
7	0,6	2,6	19,4	66,5	10,3	0,6	33,5	36,8	26,5	3,2	0	0
8	0,6	1,3	9,7	56,8	31	0,6	22,6	27,1	36,1	13,5	0,7	0
9	0	0,7	17,4	60,6	20,6	0,7	24,5	30,3	36,8	7,7	0,7	0
10	0	1,9	11	69	16,8	1,3	27,7	27,1	36,8	8,4	0	0
11	0	1,3	4,5	60,6	32,3	1,3	20,6	22,6	45,8	11	0	0

Станции: *1 - Любашёвка; 2 - Затишье; 3 - Сербка; 4 - Раздельная, 5 - Одесса; 6 - Ильичёвск; 7 - Белгород-Днестровский; 8 - Сарата, 9 - Болград, 10 - Измаил; 11 - Вилково*
Stations: *1 – Lubashivka; 2 – Zatyshye; 3 – Serbka; 4 – Rozdilna; 5 – Odessa; 6 – Ilichevsk; 7 – Belgorod-Dniestrovsky; 8 – Sarata; 9 – Bolgrad; 10 – Izmail; 11 – Vilkovo*

in Odessa region thermal perception can vary from "very cool" to "severe thermal loadings". But warm comfortable conditions (*NEET* within 18,1-24,0ºC) prevail. The most often (with repeatability 90%) comfortable conditions (moderately warm when *NEET* = 12,1-18,0 ºC and warm) are observed in Odessa in July. The largest thermal loads on the human body occur in Vilkovo and Sarata, apparently due to high temperatures. In October in most cases cool conditions occur (*NEET* = 6,1-12,0 ºC). In the southern areas (Sarata, Bolgrad, Izmail, Vilkovo) "moderately warm comfortable" (*NEET* = 12,1-18,0 ºC) thermal perception is usually observed. Their repeatability is 36-46%. Besides, there can be often observed (in 8-14% of cases) warm comfortable conditions, and in Sarata and Bolgrad - even moderate heat loads. The spatial distribution of *NEET* in January (A), April (B), July (C), October (D) is presented in Fig. 1.

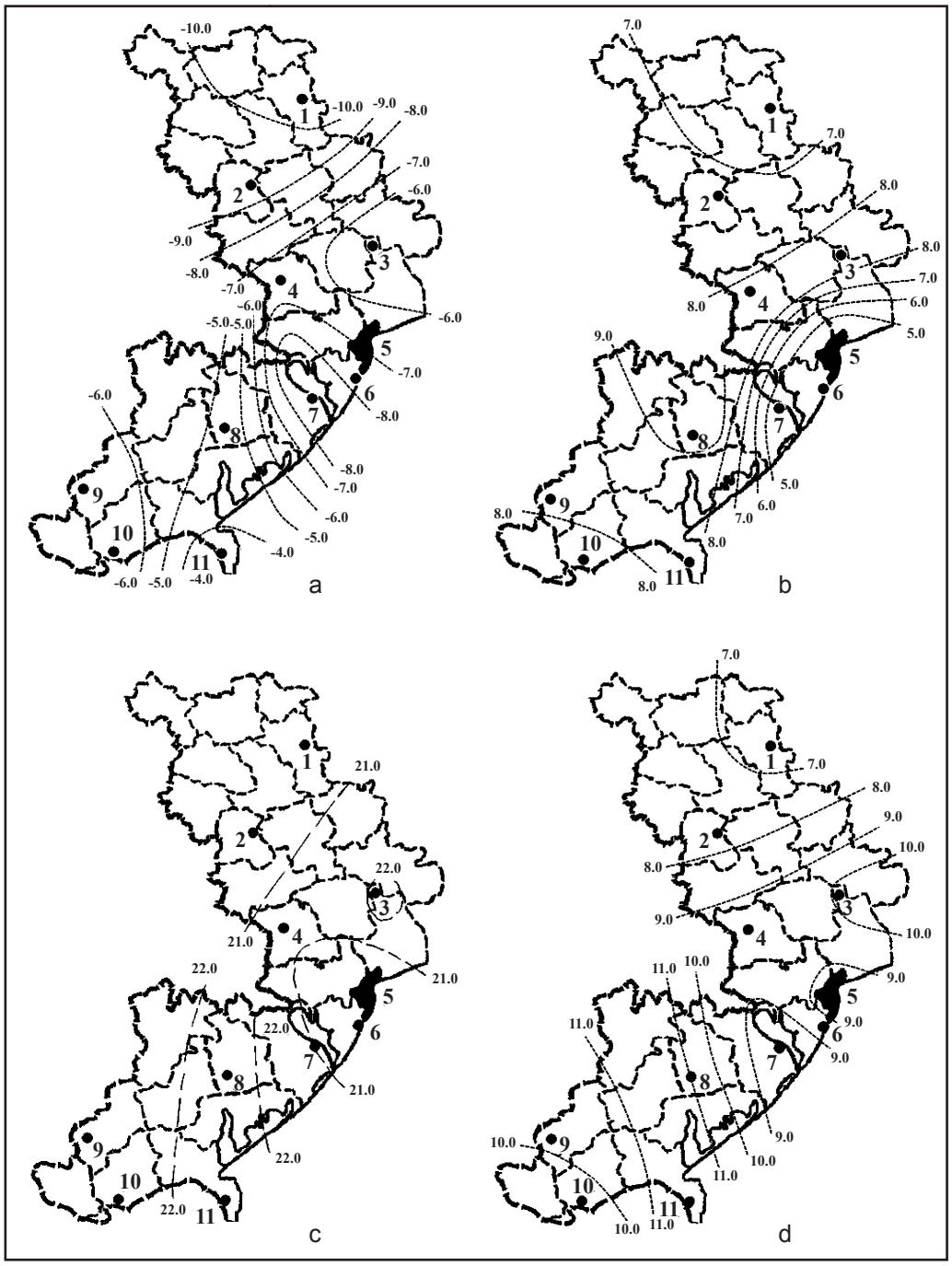

Рис. 1. Пространственное распределение НЭЭТ в январе (a), апреле (b), июле (c), октябре (d)
Fig. 1. Spatial distribution of NEET in January (a), April (b), July (c), October (d)

CONCLUSIONS

The evaluation of the complex influence of some meteorological parameters (air temperature, relative humidity and wind speed) on a human organism in January, April, July and October in Odessa region showed the following:

1. Human body usually doesn't feel of interdiurnal temperature variation in Odessa region (0-2 °C). Maximum repeatability of these values is observed, as a rule, in coastal areas. In January and October at 64% and 73% of the stations respectively, interdiurnal temperature variation exceeds 12˚C which is irritable to humans. In April repeatability of such values is much lower (only 36% of stations), and in July it is generally minimal (18%).

2. In January, comfortable humid conditions prevail throughout the region. However, the relative humidity is often above 80%. In April comfortable humid conditions preponderate in the coastal districts of Odessa region. In the rest of the area dry conditions prevail. In July favorable characteristics usually occur in Belgorod-Dniestrovsky, Odessa, Ilichevsk and Vilkovo. In October comfortable humid mode dominates in entire Odessa region (repeatability 61-74%).

3. In January very cool conditions predominate throughout the region. In April heat perception "very cool" prevails in Odessa, Ilichevsk, Belgorod-Dniestrovsky. In other areas "cool" thermal perception is more common. The most comfortable situation is in the southern territories and Serbka. In July thermal perception can vary from "very cool" to "severe thermal loadings". The most comfortable conditions are observed in July in Odessa. In October in most cases cool conditions occur. In the southern areas "moderately warm comfortable" thermal perception is usually observed.

4. Analysis of results of the calculations showed that the most favorable conditions for recreation in Odessa region among 4 central months are observed in July and October. Awareness of quantitative and qualitative estimation of bioclimatic resources can be successfully used in the treatment of a wide range of cardio-vascular, respiratory diseases, etc.

The results can be useful for planning and differentiation of tourism areas and facilities.

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